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Runway Pavement Design using the Federal Aviation Administration Method

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ABSTRACT

Dhoho International Airport is a new airport located in Kediri Regency, East Java Province, which is built on an area of + 454.5 hectares with a runway length of 3300 m and a width of 45 m. According to its hierarchy, Dhoho Kediri International Airport is a feeder airport (spoke). The B777-300ER aircraft is planned to operate at Dhoho International Airport with a plan life of 10 years which has a subgrade CBR value of 6%. The purpose of this research is to determine the thickness of flexible pavement on the runway of Dhoho Kediri International Airport using the FAA method. In determining the thickness of the runway flexible pavement using the FAA method is influenced by the number of annual departures of aircraft, the MTOW value of aircraft and the CBR value of the subgrade. To determine the annual number of aircraft departures at the new airport, it is necessary to forecast the number of passengers by considering the number of passengers at the nearest airport. Based on data analysis in this study, the total thickness of runway flexible pavement at Dhoho International Airport using FAA method is 102 cm with details of surface thickness of 13 cm, base course thickness of 56 cm, and subbase thickness of 33 cm.

Keywords: *Runway; FAA Method; Thickness Flexible Pavement*

INTRODUCTION

According to the Minister of Transportation Regulation No. 69 of 2013 concerning the national airport order in article 1 paragraph 3, it is explained that the airport is a place for taking off and landing aircraft, loading and unloading cargo and / or post, as well as up and down passengers, which is equipped with safety facilities. At the airport there are supporting components that help flight operations, namely the runway, runway or flexible pavement is a place to land and take off aircraft consisting of various layers of pavement structures, namely surface course, base course, and subbase course [1].

Planning the thickness of pavement structures at airports generally uses the FAA (Federal Aviation Administration) method of United States air transportation regulations, for airport runway pavement planning based on the CBR (California Bearing Ratio) method (FAA, 2014; FAA 2016; Purwanto, 2019) [2]. The FAA method refers to Advisory Circular (AC) No. 150/5320/6D on Airport Pavement Design and Evaluation, which is used for airport airside pavement planning using the number of annual aircraft departures and the Maximum Take Off Weight (MTOW) value of the aircraft plan [3].

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Dhoho Kediri International Airport is a new airport located in 3 sub-districts of Kediri Regency, namely Tarokan Sub-district, Banyakan Sub-district, and Grogol Sub-district which is built on an area of + 454.5 hectares with a runway length of 3300 m and 45 m width. The B777-300ER aircraft is planned to operate at Dhoho Kediri International Airport with a plan life of 10 years which has a subgrade CBR value of 6%. In accordance with its hierarchy, Dhoho Kediri International Airport is a feeder airport (spoke) [4].

MATERIALS AND METHODS

Planning the thickness of the runway flexible pavement using the FAA method is influenced by the number of annual aircraft departures and the Maximum Take Off Weight (MTOW) value and the subgrade CBR value. The steps used in data analysis in this study are:

1. Collecting the necessary data, namely:
   a. Technical data on the characteristics of aircraft plans
   b. Subgrade CBR
   c. Annual departure number of Abdul Rahman Saleh Airport Malang
2. Perform analysis related to runway flexible pavement
3. Forecasting the number of passengers.
4. Calculating the dual gear departure value (R2).
5. Calculating the wheel load design value (W2).
6. Calculating the value of wheel load design (W1).
7. Calculates the equivalent annual departure (R1) value.
8. Calculating the runway plan pavement thickness.
9. Making design drawings of runway plan pavement thickness using Autocad application.

RESULTS AND DISCUSSION

Aircraft Planning

The B777-300ER aircraft is planned to operate at Dhoho Kediri International Airport with the specifications presented in Table 1.

Table 1. Specifications of the B777-300ER aircraft planning

Specifications of the B777-300ER aircraft planning	
Wing span	64,8 m
Fuselage	73,86 m
Tail Height	18,85 m
Gear Configuration	*Triple Tandem Wheel Gear*
Maximum Take Off Weight	775.000 lbs (351.535 kg)
Maximum Landing Weight	554.000 lbs (251.290 kg)
Main Gear Tire Pressure	215 Psi (15,12 kg/cm^2)
Main Gear	2 x 6
Nose Gear	1 x 2

Forecasting Annual Departure

In this study, forecasting annual departure using the polynomial regression method and Gauss-Jordan elimination by considering the number of annual aircraft passengers at Abdul Rahman Saleh Malang Airport which can be diverted to Dhoho Kediri International Airport. For the annual departure at Abdul Rahman Saleh Airport Malang used in this study is in 2016 - 2022 The data is presented in table 2.

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Table 2. annual departure at Abdul Rahman Saleh Airport Malang

No	Year	Annual Departure
1	2016	1826657
2	2017	1172995
3	2018	1332895
4	2019	893341
5	2020	282975
6	2021	155829
7	2022	350995

Then forecasting annual departure for 10 years using the polynomial regression method and Gauss-Jordan elimination through Microsoft Excel. The polynomial regression equation is obtained from Gauss-Jordan elimination by eliminating the A matrix form into the I matrix form. The data used is presented in table 3.

Table 3. Values of x for annual departure each year

No	Year	yi	xi	xi^2	xi^3	xi^4	xiyi	xi^2yi
1	2016	1826657	1	1	1	1	1826657	1826657
2	2017	1172995	2	4	8	16	2345990	4691980
3	2018	1332895	3	9	27	81	3998685	11996055
4	2019	893341	4	16	64	256	3573364	14293456
5	2020	282975	5	25	125	625	1414875	7074375
6	2021	155829	6	36	216	1296	934974	5609844
7	2022	350995	7	49	343	2401	2456965	17198755
Total		6015687	28	140	784	4676	16551510	62691122

From table 3, it can be used to determine the polynomial equation by using 2 steps, namely, first by matrix calculation and the second using Microsoft Excel application. The matrix calculation used is a 3 x 4 matrix according to formula 2.1, so that according to table 4.2 the following matrix is obtained:

$$\begin{bmatrix} 7 & 28 & 140 \\ 28 & 140 & 784 \\ 140 & 784 & 4676 \end{bmatrix} \begin{bmatrix} a0 \\ a1 \\ a2 \end{bmatrix} = \begin{bmatrix} 6015687 \\ 16551510 \\ 62691122 \end{bmatrix}$$

The matrix form is used to determine the polynomial regression equation with the Gauss-Jordan method, so that the results are obtained:

$$\overset{A}{\begin{bmatrix} 7 & 28 & 140 \\ 28 & 140 & 784 \\ 140 & 784 & 4676 \end{bmatrix}} \overset{B}{\begin{bmatrix} 6015687 \\ 16551510 \\ 62691122 \end{bmatrix}} = \begin{bmatrix} :7 \\ -\ a21 \times a11 * \\ -\ a31 \times a11 * \end{bmatrix}$$

$$\overset{A*}{\begin{bmatrix} 1 & 4 & 20 \\ 0 & 28 & 224 \\ 0 & 224 & 1876 \end{bmatrix}} \overset{B*}{\begin{bmatrix} 859383,9 \\ -7511238 \\ -57622618 \end{bmatrix}} = \begin{bmatrix} a11 * \ -(a21 * \times b2 **) \\ :28 \\ a31 * \ -(a32 * \times b2 **) \end{bmatrix}$$

$$\overset{A^{**}}{\begin{bmatrix}1 & 0 & -12\\0 & 1 & 8\\0 & 0 & 84\end{bmatrix}}\overset{B^{**}}{\begin{bmatrix}1932418\\-268259\\2467286\end{bmatrix}} = \begin{bmatrix}a13^{**} - (a13^{**} \times b3^{***})\\a23^{**} - (a23^{**} \times b3^{***})\\ :84\end{bmatrix}$$

$$\overset{A^{***}}{\begin{bmatrix}1 & 0 & 0\\0 & 1 & 0\\0 & 0 & 1\end{bmatrix}}\overset{B^{***}}{\begin{bmatrix}2284887\\-503238\\29372{,}45\end{bmatrix}} = \begin{bmatrix}a0\\a1\\a2\end{bmatrix}$$

$$\begin{bmatrix}a0 & 0 & 0\\0 & a1 & 0\\0 & 0 & a2\end{bmatrix} = \begin{bmatrix}2284887\\-503238\\29372{,}45\end{bmatrix}$$

$$\begin{bmatrix}a0\\a1\\a2\end{bmatrix} = \begin{bmatrix}2284887\\-503238\\29372{,}45\end{bmatrix}$$

So the equation obtained in the Gauss-Jordan method is Y = 29372.45x2 - 503238x + 2284887.

In addition to matrix calculations to determine the polynomial regression equation can use Microsoft Excel applications as shown in Figure 1.

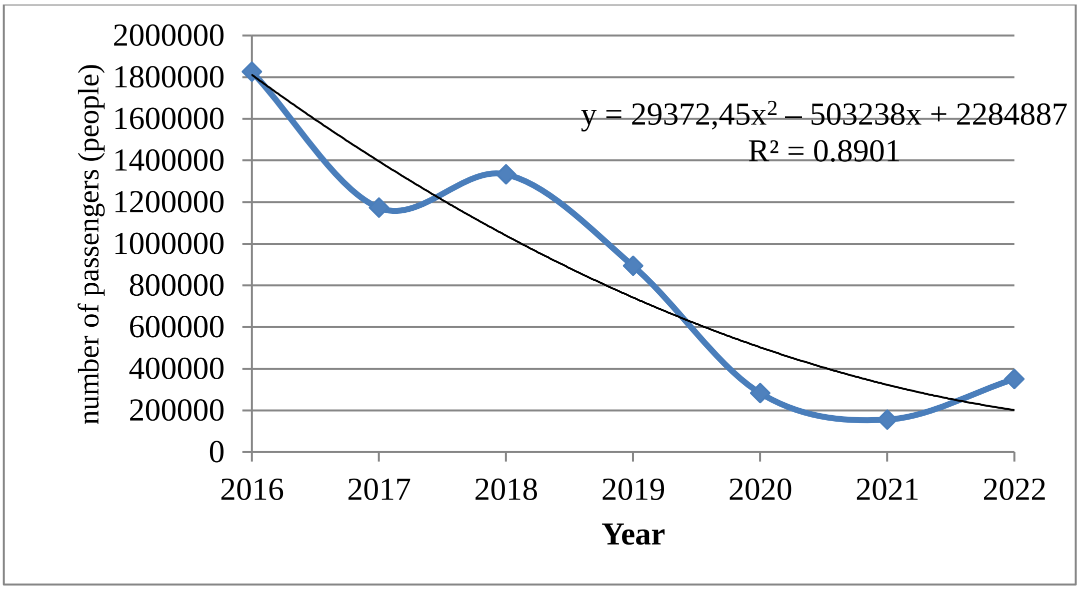

Figure 1. Polynomial regression graph of annual departure at Abdul Rahman Saleh Airport Malang

From Figure 1, the equation Y = 29372.45x2 - 503238x + 2284887 is obtained with an R-Square value of 0.89. The polynomial graph shown in Figure 1 decreased from 2016 - 2022, but in 2022 the graph began to increase. It can be estimated that there will be an increase in the annual departures in the following year. Furthermore, the forecasting calculation of the annual departures in 2032 that can be diverted to Dhoho Kediri International Airport with data processing is presented in table 4.

Table 4. Forecasting annual departure at Abdul Rahman Saleh Airport Malang

No	Tahun	X	a2	a1	a0	x^2	Y
1	2023	8	29372.45	-503238.1	2284887.3	64	138819
2	2024	9	29372.45	-503238.1	2284887.3	81	134913
3	2025	10	29372.45	-503238.1	2284887.3	100	189751
4	2026	11	29372.45	-503238.1	2284887.3	121	303335
5	2027	12	29372.45	-503238.1	2284887.3	144	475663
6	2028	13	29372.45	-503238.1	2284887.3	169	706736
7	2029	14	29372.45	-503238.1	2284887.3	196	996554
8	2030	15	29372.45	-503238.1	2284887.3	225	1345117
9	2031	16	29372.45	-503238.1	2284887.3	256	1752425
10	2032	17	29372.45	-503238.1	2284887.3	289	2218478

So, the number of aircraft passengers that can be diverted from Abdul Rahman Saleh Airport Malang to Dhoho Kediri International Airport in 2032 is 2218478 people.

Dual Gear Depature **(R2)**

Data forecasting annual departure of aircraft in 2032 must be calculated by dividing the average value by the life of the plan [5]. To calculate the value of annual departure data used as follows:

Forecasting annual departure in 2032 = 2218478 people
Age plan = 10 years
So obtained,
Annual departure value = annual departures: plan life
= 2218478: 10
= 221847,8
≈ 221848 thousand people

After obtaining the annual departure value, then determine the value of dual gear departure (R2). Dhoho Kediri International Airport uses the B777-300ER aircraft plan which has a dual tridem main gear configuration. The type of landing gear configuration of each type of aircraft plan needs to be converted into a dual wheel aircraft landing gear to determine the dual gear departure (R2) wheel load value [6]. The aircraft main gear conversion factors are presented in table 5.

Table 5. Conversion factor of aircraft landing gear

Konversi Dari	Ke	Faktor Pengali
Single Wheel	*Dual Wheel*	0,8
Single Wheel	*Dual Tandem*	0,5
Dual Wheel	*Dual Tandem*	0,6
Double Dual Tandem	*Dual Tandem*	1,0
Dual Tandem	*Single Wheel*	2,0
Dual Tandem	*Dual Wheel*	1,7
Dual Wheel	*Single Wheel*	1,3
Double Dual Tandem	*Dual Wheel*	1,7

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According to Gopalakrishnan/Thompson (2006), the shock load generated by a B777-300ER aircraft with a dual tridem main gear configuration is equal to the shock load generated by an aircraft with a double dual tandem main gear configuration. Therefore, the conversion factor is 1.7 [6].
To determine the value of dual gear departure the data used are:
Annual departure = 221848
landing gear conversion factor = 1.7
The formula for calculating dual gear departure is as follows:
R2 = annual departure value x Landing gear conversion factor
= 221848 x 1,7
= 377141,6
≈ 377142
So, the R2 value is 377142

Wheel Load Design **(W2)**
In the calculation of the aircraft wheel load design rests on the main landing gear, so it is considered 95% of the MTOW is supported by the main landing gear [6]. To calculate the wheel load design of an aircraft, the following data is known:
MTOW of the B777-300ER aircraft = 775,000 lbs.
Total main gear of aircraft B777-300ER = 6 pieces
Total nodse gear of aircraft B777-300ER= 2 pieces

In determining the value of wheel load design using formula 3.2, namely,

$$W2 = 0{,}95 \text{ x MTOW x } \frac{1}{\text{total main gear}} \text{ x } \frac{1}{\text{total nose gear}}$$
$$= 0.95 \text{ x } 775.000 \text{ x } \frac{1}{6} \text{ x } \frac{1}{2}$$
$$= 61.354{,}17 \text{ lbs}$$

Wheel Load Design **(W1)**
Wheel load design (W1) is the main gear load value on the aircraft that has the largest mixed aircraft main gear load value (W2). At the new airport, the W1 value uses the planned aircraft that will operate at the airport. so that the W1 value is the same as W2 [5].
It is known that the value of W2 = 61,354.17 lbs.
Therefore, the value of W1 = W2
W1 = 61,354.17 lbs

Equivalent Annual Departure **(R1)**
To calculate the Equivalent Annual Departure of an aircraft, the following data is known:
R2 = 377142
W1 = 61,354.17 lbs
W2 = 61,354.17 lbs

The formula for calculating Equivalent Annual Departure is as follows:

$$\text{Log R1} = \log \text{R2} \sqrt{\frac{W2}{W1}}$$
$$\text{Log R1} = \log (377142) \text{ x } \sqrt{\frac{61.354{,}17}{61.354{,}17}}$$
$$\text{Log R1} = 5{,}577 \text{ x } 1$$

R1 $= 10^{5,577}$
R1 $= 377572,19$
R1 ≈ 377572

Determining the Thickness of Runway Flexible Pavement

Determination of runway flexible pavement thickness using the FAA method can be done using a graph as shown in Figure 2.

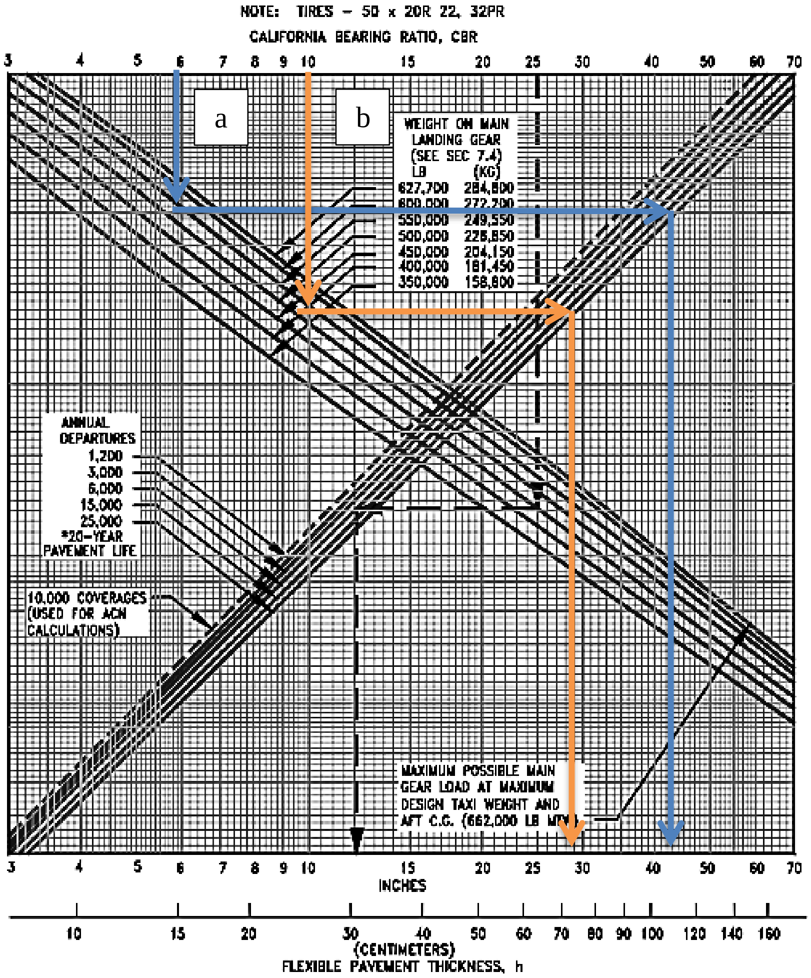

Figure 2. FAA method total runway pavement thickness value

a. Total runway pavement thickness value
   By using the graph presented in Figure 2. Determination of the total runway pavement thickness by placing the subgrade CBR value of 6% on the top side of the CBR section graph and draw a vertical line down to intersect with the Weight On Main Landing Gear of 554,000 lbs. From this point draw a horizontal line to the right intersecting with the equivalent annual departure R1 of 377572. Then pull the vertical line down and get the total flexible pavement thickness value on the runway of 42 inches (107 cm).
b. Subbase layers thickness
   Determination of the 10% CBR subbase thickness using the graph in Figure 2. In the same way as determining the total runway pavement thickness. Then the value of the thickness of the subbase layer with a 10% CBR value of 29 inches (74 cm) is obtained.

Thickness of subbase layer = total flexible pavement thickness - 10% subbase thickness
= 42 inches - 29 inches
= 13 inches
= 33.02 cm
≈ 33 cm

c. Surface thickness
In the Advisory Circular 150-5320-6D regulation on Airport Pavement Design and Evaluation it is explained that the surface thickness value for the type of double dual tandem landing gear configuration in critical areas is 5 inches (12.7 cm) while in non-critical areas the surface thickness value is 4 inches (10.16 cm).

d. Base course thickness
The calculation of base course thickness is as follows,
Base course thickness = subbase thickness - surface thickness
= 29 inches - 5 inches
= 24 inches
= 60.96 cm
≈ 61 cm

The calculation results were first tested with the graph in Figure 3. by comparing the minimum base course thickness required. The minimum subbase thickness results are presented in Figure 3.

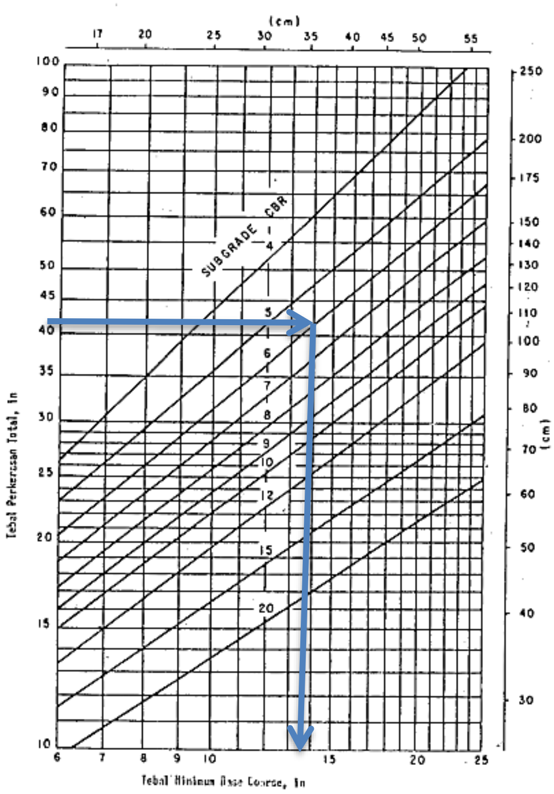

Figure 3. Minimum base course thickness value

To determine the minimum base course thickness by placing the total pavement thickness value of 42 inches on the left side of the pavement thickness section graph then draw a horizontal line to the right to the point of the predetermined subgrade CBR value and draw a

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vertical line down. This results in a minimum base course thickness of 14 inches (36 cm) which is used to determine the base course thickness from the calculation. If the calculated base course thickness is less than the minimum base course thickness, the minimum base course thickness is used. If the calculated value of the base course thickness is more than the minimum base course thickness, the calculated base course thickness is used [7].

So, the conclusion of the calculation of the thickness of the flexible pavement of the runway of Dhoho Kediri International Airport using the FAA method obtained a total pavement thickness of 107 cm with a surface thickness of 13 cm, a subbase thickness of 61 cm, and a subbase thickness of 33 cm. For details of the thick cross section of flexible pavement using the FAA method, it is shown in Figure 4.

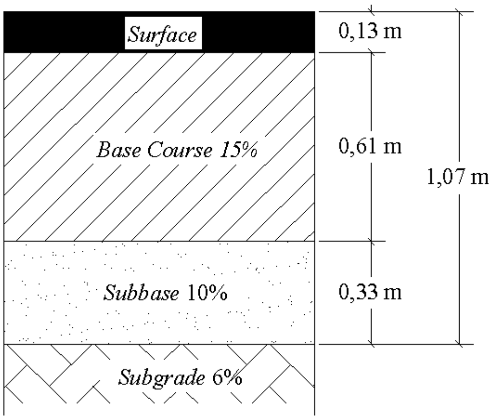

Figure 4. Thickness of flexible pavement using FAA method

CONCLUSION

The calculation of runway flexible pavement thickness using the FAA method is influenced by the value of the annual number of aircraft departures and the Maximum Take-Off Weight (MTOW) of the planned aircraft. If planning flexible pavement at a new airport, forecasting the number of passengers is needed to determine the number of annual aircraft departures. Based on the results of data analysis and calculation of the total flexible pavement thickness of the runway of Dhoho Kediri International Airport if planned using the FAA method, the total thickness of the runway flexible pavement is 102 cm with details of surface thickness of 13 cm, basecourse thickness of 56 cm, and subbase thickness of 33 cm.

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